

# Contrast sensitivity in children and adults

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**SUMMARY** Contrast sensitivity functions to vertical sinusoidal gratings have been measured in 135 subjects ranging from 3 to 29 years of age. The reported contrast sensitivities for all spatial frequencies increased steadily with age, reaching adult levels during adolescence. The usefulness of these functions as a clinical test is discussed.

Contrast sensitivity to gratings has been used to investigate the physiology of the visual system in animals<sup>1</sup> and in man.<sup>2</sup> Recently there have been several reports of the value of such an approach to clinical practice.<sup>3,4</sup> The conventional test of visual performance is the Snellen letter chart, which indicates the finest resolvable detail at high contrast. Since the visual world consists of images of different sizes at varying contrast levels, a Snellen test reveals the functioning of only one aspect of the visual system. Measurements of contrast sensitivity indicate the contrast levels required to distinguish objects of different size from their background. Contrast sensitivity function (CSF) is the graphical representation of threshold contrast to detect gratings of different spacing (spatial frequency). Several studies support the contention that CSF gives a more complete analysis of visual performance than a Snellen test. It has been found, for example, that patients with cerebral lesions who were complaining of visual problems often had severely abnormal CSFs despite normal Snellen acuities.<sup>5</sup> Also CSFs have been found to be reduced in multiple sclerosis patients before any other visual disturbances were evident, suggesting the value of the technique for earlier detection of the disease.<sup>6</sup>

Studies of contrast sensitivity in younger ages have been restricted almost entirely to the first year of life. These have suggested markedly reduced values compared to adults.<sup>7</sup> Recently a brief report on mean CSFs in different age groups has suggested that children do perform at lower levels than adults.<sup>8</sup> We have investigated the possibility of extending CSF measurements to younger children and have tested a larger number of subjects to

analyse change with age. This series may form the basis for assessment of contrast sensitivity in children.

## Materials and methods

Caucasian children aged 3 to 15 years and adults 18 to 29 years were subjects in this study. In each age group approximately equal numbers of males and females were tested. All subjects were volunteers. 86% of them were given an ophthalmological examination. Those over 6 years were required to have an uncorrected Snellen acuity of 6/6 or better for distance and those under 6 years an uncorrected acuity of 6/9 by the E test. The 14% not given an ophthalmological test were distributed over all age groups.

Vertical sinusoidal gratings were generated in the conventional way<sup>2</sup> on a display monitor (Tektronix 604 P31 fast-decay phosphor). The average luminance was 9 cd/m<sup>2</sup> and varied from peak to trough between 14 cd/m<sup>2</sup> and 4 cd/m<sup>2</sup> giving a maximum contrast value of 0.5, contrast being defined as  $(L_{\max} - L_{\min}) / (L_{\max} + L_{\min})$  where  $L_{\max}$  and  $L_{\min}$  are the maximum and minimum luminances respectively of the gratings display. Observers sat 1 metre from the display, which was viewed binocularly with natural pupils through a circular window mounted on the face of the monitor such that the display subtended 6 degrees. The surround was approximately matched for luminance and colour. Room luminance was approximately 2 cd/m<sup>2</sup>. An experimenter sat beside the subject and showed samples of gratings, varying the spatial frequency and contrast. The subject's task was to report when any lines were visible. Special care was taken to ensure the instructions were understood. Subjects were asked to keep their heads straight and at the measured distance; this was checked on a video-

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Table 1 *Mean contrast sensitivity at each spatial frequency for all age groups*

Age (years)	Number of subjects	Spatial frequency (cycles/degree)						
		0.25	0.5	1	2	4	8	16
3—	6	1.9	3.0	6.3	9.4	13.0	5.9	1.5
4—	17	2.0	4.7	7.4	10.5	15.0	7.2	1.9
5—	14	2.1	3.5	10.5	17.7	15.6	8.2	2.0
6—	15	1.7	5.5	11.7	23.0	32.5	13.8	2.4
7—	17	2.3	7.2	14.6	28.0	34.5	16.0	2.6
8—	14	3.1	8.2	14.4	28.2	37.0	17.7	3.1
9—12 (mean 11.5)	20	3.3	11.2	17.8	35.7	57.0	28.5	4.3
12—15 (mean 13.3)	15	4.3	14.3	19.5	58.5	75.6	32.5	7.0
18—29 (mean 22.5)	17	4.4	17.0	31.5	58.5	70.0	28.0	5.5

monitor by a second experimenter. The contrast levels were controlled by 2 attenuator knobs operated by the experimenter, a coarse control which changed contrast in 10 dB steps and a fine control with 1 dB divisions.

Threshold for detection of the grating was estimated by a modified yes/no staircase technique,<sup>9</sup> the direction of the change in contrast being reversed when the report changed. The size of the contrast change was reduced at each reversal until steps of 1 dB attenuation were reached. Threshold was taken as being the contrast midway between consistent yes and no responses.

Seven spatial frequencies (0.25, 0.5, 1.0, 2.0, 4.0, 8.0, and 16.0 cycles/degree) were presented randomly so that no adjacent frequencies were tested consecutively. Between presentations of each spatial frequency, to prevent boredom or habituation effects, subjects were shown colour transparencies of a cartoon character or animals overlaying the test display and its surround; these matched the test surround in overall luminance.

## Results

Data are presented on 135 subjects aged from 3 years to adult. All subjects over 4 years of age completed the test satisfactorily; in the 3–4 age group only 6 children out of 24 tested could be included. The short attention span of this age group was the main difficulty.

A clear picture emerged from this study in that there was a steady rise in mean contrast sensitivity with age. The results are presented in Table 1. There was almost no overlap between mean CSFs for each age group. For reasons of clarity a represen-

tative sample of mean CSFs in different age groups is shown in Fig. 1. Mean CSFs for all the age groups differ only in height but not in overall shape, the peak sensitivity being at about 4 cycles/degree throughout. The rate of increase in contrast sensitivity appears to be constant for all the spatial frequencies tested.

The data were analysed for sex differences in all age groups and at all spatial frequencies. None were found, except that in the 3–4 age group only girls completed the test. A typical result is shown in Fig. 2, which illustrates the rise in contrast sensitivity to a 2 cycle/degree grating with age for both sexes.

## Discussion

We are reporting a series of CSF curves in a total of 135 children and adults. There is an increase with age in contrast sensitivity for all spatial frequencies which levels off in early adolescence. Since CSF measures are proving valuable in the assessment of adult visual performance it is clearly desirable to extend this test to children. We have found the assessment of CSFs by the staircase method is possible for the majority of children above 4 years and a few even younger. Although there is some individual variation in the results of the test, the general trend of increased reported sensitivity with age is clear. A test session lasts only 15–20 minutes but does in its present form require sophisticated equipment; a set of Arden plates<sup>10</sup> modified for paediatric use might prove to be a practical solution.

There has been an earlier report of CSF in young people.<sup>8</sup> The mean values of one 8-year-old and two 15-year-olds show a reduced sensitivity at low

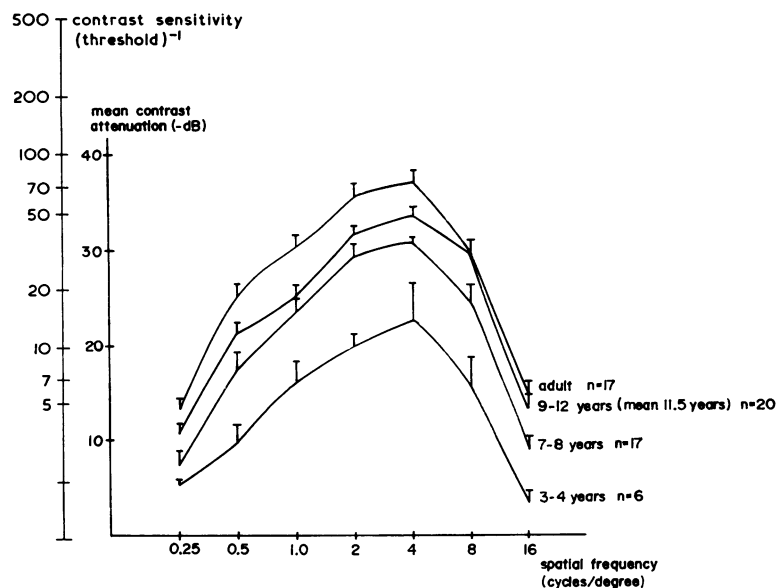


Fig. 1 Mean contrast sensitivity (reciprocal of contrast threshold) plotted as the function of spatial frequency for subjects in 4 age groups. The vertical bars represent  $\pm$  the standard error of the mean. Contrast attenuation, expressed in decibels ( $-dB$ ) is also shown.

frequencies compared to adults (18–29 years). However, in our more extensive series we have found that sensitivity for all spatial frequencies increases with age, to maximum levels in the 18–29 age group. It is possible that the older subjects (30–39 years) in this study were already showing reduced sensitivity to high spatial frequencies, a trend which was marked in the 45–66 year age group.

It is a maxim of clinical practice that early detec-

tion of visual problems is most important if therapy is to be successful. There seems to be a sensitive period in early childhood when neural connections are relatively plastic. Inappropriate neural circuitry may develop as a result of early abnormal visual experience, and this usually becomes irreversible later in life.<sup>11</sup> Studies of visual deprivation in cats and monkeys have suggested the anatomical and physiological changes which probably underlie<sup>12,13</sup>

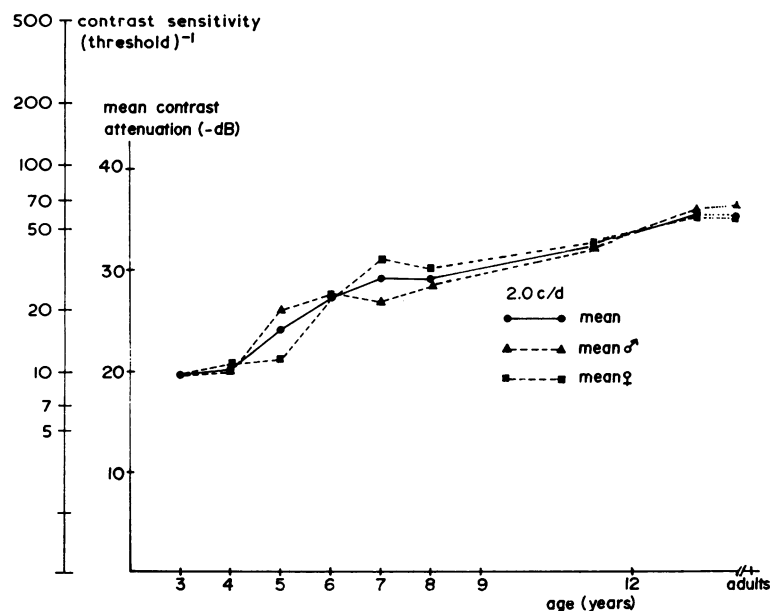


Fig. 2 Mean contrast sensitivity plotted as a function of age for a 2 cycles/degree grating; changes with age for males and females are shown. Contrast attenuation, expressed in decibels ( $-dB$ ) is also included.

the clinical findings. In the context of early detection of visual problems, such as amblyopia, the application of the CSF may prove useful. Hess and Howell<sup>14</sup> have found that amblyopes fall into 2 classes, those with decreased sensitivity at all spatial frequencies and others with a loss only in the higher frequencies. The prognostic value of this observation has yet to be investigated.

When this normal series is considered it appears that there are several factors which are likely to have contributed to our results. It is known that contrast sensitivity increases<sup>15</sup> and refractive properties change<sup>16</sup> with age. While this is reflected in our data, variations in the criteria adopted by individual subjects may also have influenced our findings. In adult subjects such differences are known to affect the height but not the shape of the CSF curve.<sup>17</sup> The naivete of the adult subjects used in this study probably explains the rather low values we have found compared to other reports.<sup>17</sup> Young subjects could also adopt criterion levels which vary between individuals of any one age group, accounting for some of the variability in our data. In addition there may be differences between age groups in the stringency of the criteria adopted. Use of a forced choice procedure would, according to signal detection theory,<sup>18</sup> minimise criterion effects. However, it is a method requiring co-operation of the subject for several hours and is thus unlikely to be practical for visual assessment in children. This method provides a satisfactory estimate within a reasonable time and is thus useful for clinical practice. The significance of any deviation in a subject from our data is still a matter of judgment. As more information becomes available, it may be possible to quantify these differences.

In conclusion, we consider that use of the contrast sensitivity function may well prove valuable in conjunction with the more conventional tests of vision in children.<sup>19</sup> It may also be useful in furthering our understanding of the development, diagnosis, and treatment of ophthalmological problems such as amblyopia.

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